Dune Formations Associated with Multiple Redd Construction by Chinook Salmon in the Upper Nechako River, British Columbia, Canada.

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DUNE FORMATIONS ASSOCIATED WITH MULTIPLE REDD CONSTRUCTION BY CHINOOK SALMON IN THE UPPER NECHAKO RIVER, BRITISH COLUMBIA, CANADA.

by

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ABSTRACT

Spawning areas in the Upper Nechako River, located in central British Columbia, contain dunes situated perpendicular to the river flow that range in length to 15 meters and rise up to .75 meter in height. Observations made during the 1974 chinook salmon (Oncorhynchus tshawytscha) (Walbaum, 1792) spawning period indicate that the dune formations and their annual maintenance is related to multiple chinook redd construction patterns. The submerged dunes also created holding refuges for chinook salmon during spawning, and is believed to provide enhanced subsurface water circulation improving intra-gravel egg incubation flows.

Key words: chinook salmon, spawning, multiple redds, dune formations, incubation.

RESUMÉ

Dans la partie supérieure de la rivière Nechako située au centre de la Colombie-Britannique, les frayères contiennent des dunes perpendiculaires à l'écoulement dont la longueur et la hauteur peuvent atteindre 15 m et 0,75 m respectivement. Des observations réalisées en 1974 au cours de la fraie du saumon quinnat (Oncorhynchus tsawytscha) (Walbaum, 1972) révèlent que la formation de dunes et leur présence continue sont reliées à de multiples modes de construction de nids. Les dunes submergées servent aussi de refuge au saumon pendant la fraie et peuvent accroître la circulation de l'eau sous la surface, ce qui entraîne une meilleure aération des oeufs incubant dans le gravier.

Mots-clés: saumon quinnat, fraie, nids multiples, formation de dunes.

1.0 INTRODUCTION

The Nechako River is tributary to the Fraser River at Prince George, British Columbia, Canada. The study area consisted of a 3.25 km. reach of river approximately 8 km. downstream of Cheslatta Falls, the upstream barrier to salmon migration, Figure 1.

During September 1974, observations were made on chinook salmon (Oncorhynchus tshawytscha) spawning in the Upper Nechako River. The spawning area in this part of the river is unusual in that it contains variably-sized dunes ranging in size up to .75 meter in height and 15 meters in length and situated perpendicular to the river flow. In this report these formations will be referred to as multiple redds or dunes. When chinook salmon commence nest or redd construction during spawning, the female turns on either side and makes a series of powerful flexions with body and tail. The strong suction created by these flexions, coupled with the ambient water velocity, carries gravel and silt a short distance downstream. This material forms a semi-circular pile referred to as a tailspill.

Burner, (1951) reporting on the characteristics of spawning nests of Columbia River salmon, described the following sequence of events during the construction of a chinook salmon redd:

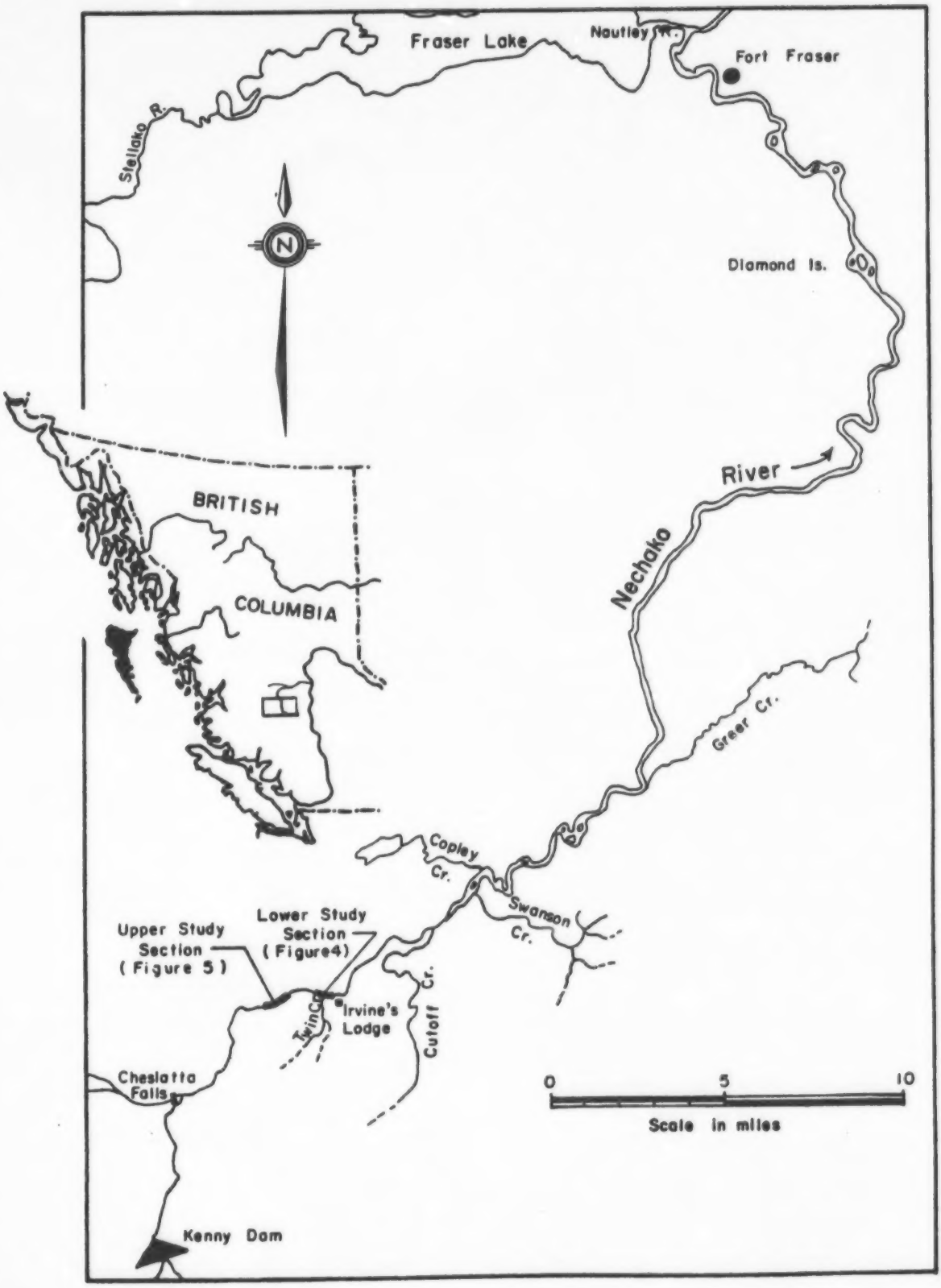


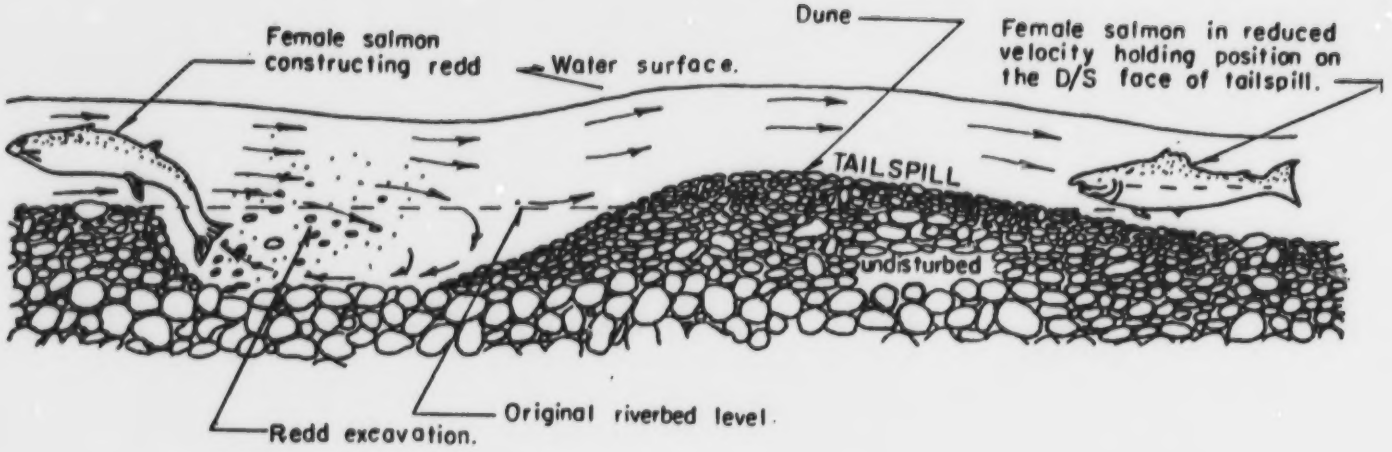
Figure 1. Upper Nechako River

> "Pre-spawning digging of salmon may last for as many as five days. At this stage, the nest is ready for egg deposition. The female alternatively digs the redd and settles back into the depression to release eggs, where-upon the male moves quickly alongside the female and releases sperm in a milky cloud that settled briefly in the bottom of the depression fertilizing the eggs. During the spawning stage, the redd increases considerably in length and depth. The post-spawning stage commences upon termination of egg deposition. The male is no longer attentive. The spent female continues to dig at the gravel with weakening efforts until she dies. This post-spawning digging, which may continue for ten days, becomes shallow, off-centre, and ineffective. A mature redd is considered to be one in which all egg-laying activities have been concluded, and some post-spawning digging has occurred," Figure 2.

These same characteristics were observed in the 1974 spawning period on the Nechako River. This report attempts to describe how multiple redds or dunes were formed within the wetted perimeter of the river and suggests they may be beneficial to the propagation of Nechako River chinook salmon stocks.

1.1 Escapement History

The only known anadromous fish that utilize the Upper Nechako River above Fort Fraser are chinook salmon and occasionally sockeye salmon (Oncorhynchus nerka (Walbaum)). Predevelopment chinook escapements in the range of 2,000 - 5,000 fish were recorded in 1937, 1940, 1949, 1951, 1952, Table 1. The Aluminum Company of Canada (ALCAN) altered the drainage of the Nechako River by constructing the earth fill Kenny Dam, which was completed on October 8, 1952. At the time the dam was completed,



[from Burner,(1951)]

Figure 2. Typical method of constructing a redd. The female strikes the gravel with her tail and the current carries gravel and silt a short distance downstream creating the tailspill.

the flow of the Nechako River was interrupted while the reservoir filled. In 1957 a gated spillway structure located on Skins Lake, approximately 160 km. west of Kenny Dam, began releasing the overlow from the reservoir back via the Cheslatta River drainage into to the Nechako River approximately 10 kilometers downstream from Kenney Dam.

The chinook salmon runs declined drastically after construction of the dam reaching a low of less than 100 chinook spawners in 1960. Since 1960, the run has gradually recovered so that in excess of 2,600 chinook spawned successfully in the Nechako River in 1978. The 1978 run was the largest on record since the construction of Kenny Dam.

More detailed accounts of the historical chinook escapement to the Nechako River are provided in a report by the Fisheries and Marine Service (1979), Fraser et al. (1982) and the 1985 Canadian Agency Report on Chinook Salmon (1986).

TABLE 1: ESTIMATED ESCAPEMENT OF CHINOOK SALMON IN THE NECHAKO RIVER FROM 1934 TO 1985[a]

Year	Chinook Escapement	Year	Chinook Escapement	Year	Chinook Escapement
1934	100-300	1952	4000**	1970	500-1000
1935	1000-2000	1953	300-500	1971	300-500
1936	500-1000	1954	1000-2000	1972	300-500
1937	2000-5000	1955	300-500	1973	500-1000
1938	500-1000	1956	100-300	1974	1424***
1939	1000-2000	1957	No est.	1975	1000-2000
1940	3000*	1958	No est.	1976	1200*
1941	1000-2000	1959	No est.	1977	2000*
1942	300-500	1960	50-100	1978	2600*
1943	100-300	1961	300-400*	1979	1800*
1944	100-300	1962	300-500	1980	2000****
1945	1200-1300*	1963	300-500	1981	1540*****
1946	1000*	1964	600-800*	1982	1448*****
1947	No est.	1965	300-500	1983	800-900*
1948	No est.	1966	400-500*	1984	1300*
1949	2000-5000	1967	500-1000	1985	2000*
1950	1000-2000	1968	300-500		
1951	2000-5000	1969	500-500		

* Specific numerical estimate by local Fisheries Officer.
** Redd Count, McLaren (1952)
*** Redd Count, FMS/DFE (1979)
**** Envirocon *1984)
***** Redd Count AFrina (1982 or 1983)

[a] 1986 Canadian Agency Report on Chinook Salmon, (March 1986).

2. Survey Methodology

Two reaches of the Nechako River, historically utilized by spawning chinook salmon , contained extensive dune formations. The first area, located 8.0 km. downstream of Cheslatta Falls, isapproximately 1,000 meters long, and the second, 1.6 km. further downstream, is approximately 375 meters in length. Both study areas were surveyed to determine the bottom profiles. Each area was subdivided by cross-sections spaced approximately 70 meters apart. The upper study area consisted of 16 cross-sections, and the lower area of 6 cross-sections. Contour maps of both study areas were drawn. Five survey stations were established in the upper study site and three in the lower site. The stations were selected as the most advantageous for survey triangulation (Figure 3) to determine new salmon redd placement; standard survey techniques were employed.

Prior to the spawning period, on September 6, 1974, a survey of both study areas was undertaken to determine the location of existing dunes. Five successive surveys were conducted seven days apart throughout the spawning period. Newly constructed redds were located and coded on the contour maps with different symbols representing each of the five surveys.

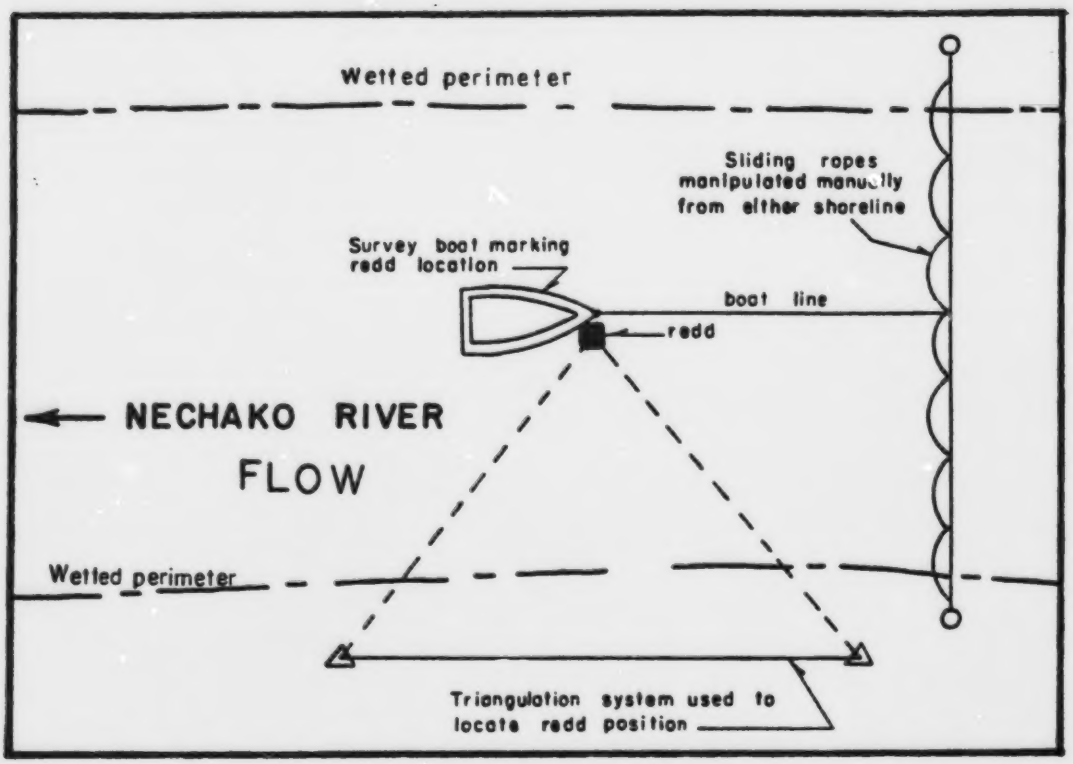


Figure 3. Procedure used in marking redd locations.

3.0 RESULTS AND DISCUSSION

3.1 Spawning Conditions

The Nechako River discharge was maintained between 25.5 and 28.3 cu.m./sec. (900 - 1,000 cubic feet per second) for the duration of the spawning period by regulating the flow control structure at the Skins Lake Spillway. The flow was substantially lower than in pre-1974 chinook spawning runs. The reduced flow in the study sites confined the approximately 200 spawning chinook to a restricted wetted channel area that would have normally contained greater depths and velocities at higher discharges. The river bottom gravel composition was suitable for salmon spawning throughout the riverbed except in those areas that comprised the extreme low flow channel which consisted of larger boulder material that appeared unsuitable for spawning.

The spawning areas were directly associated with the submerged dunes in the study regions. The low velocity zones located on the downstream side of these dunes were utilized as refugia by chinook salmon during the redd construction phase. This behavior is thought by the author to be a method to conserve energy. Due to the small number of salmon spawning in the study areas, it was presumed that redd construction sites were selected by the salmon in optimal physical locations; depths ranged between .55 to 1.03 meters and had a nose velocity range of .43 to .75 meters per second (Fisheries and Marine Service, 1979). A

total of 101 redds were constructed in the two study areas in 1974, 34 in the lower and 67 in the upper study sites, (See Figures 4 and 5).

3.2 Multiple Redds

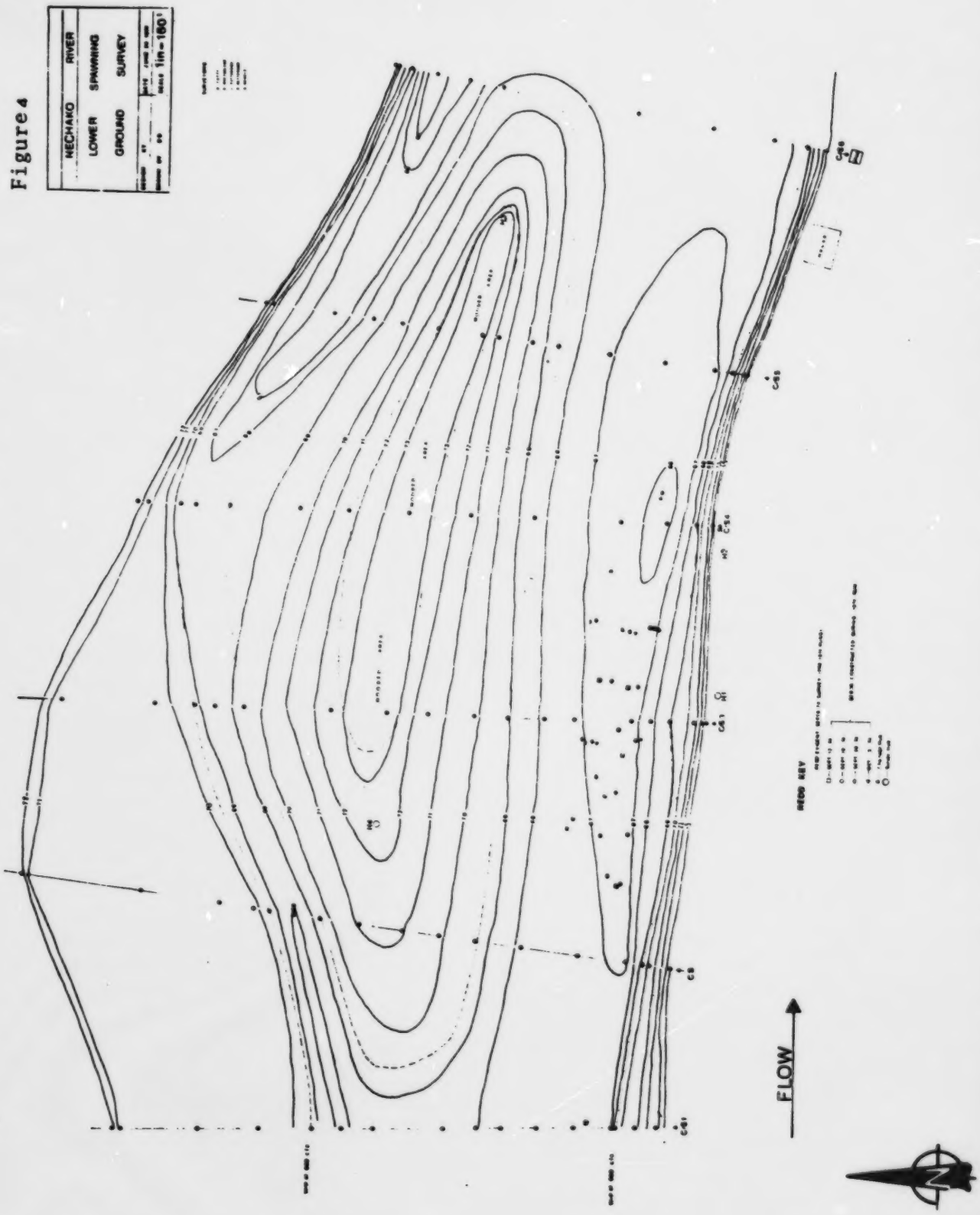
The construction of multiple redds was observed in a manner that created new dunes as well as variable formations on existing dunes.

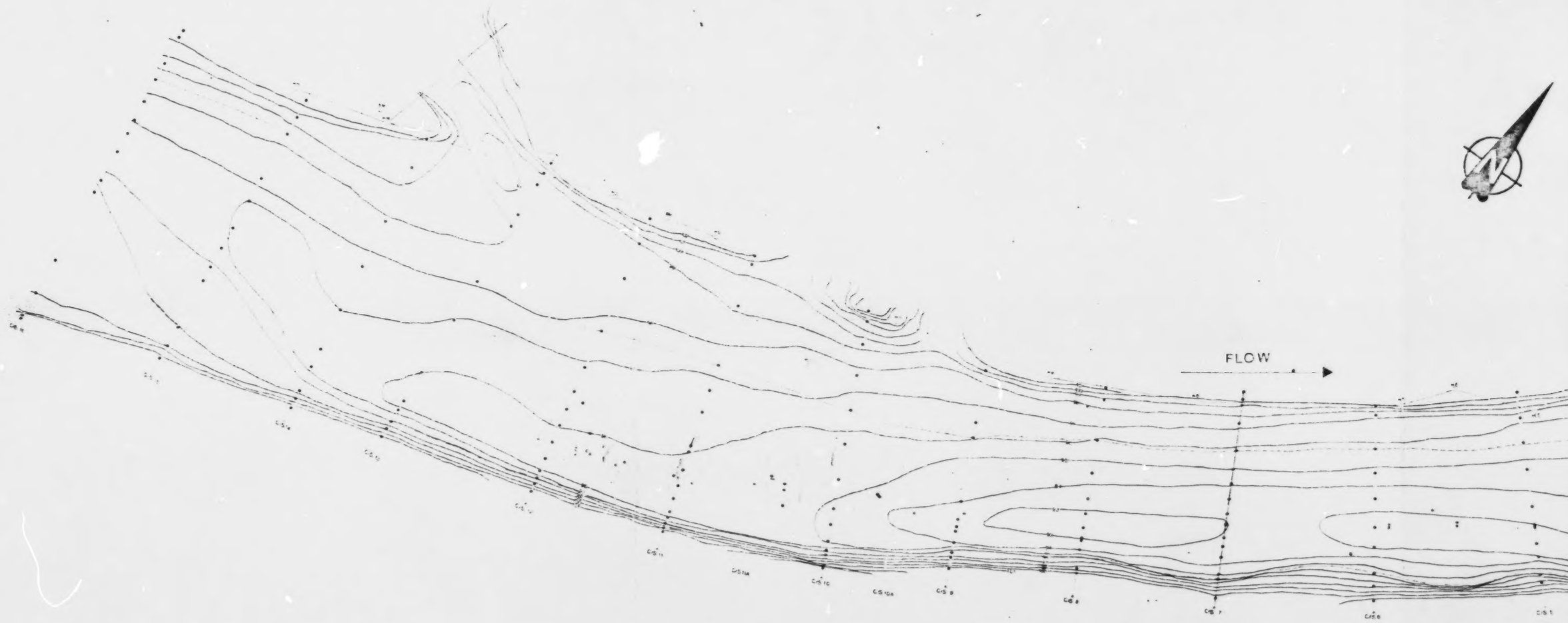
3.2.1 A New Dune Formation

The formation of a new dune was observed during the period of September 5 to 12, 1974. Two redds were constructed 5 meters apart in a line perpendicular to the river flow in an area devoid of previous redd or dune formations. After completion of these initial two redds, the female chinooks died and then a third redd was excavated between the previously two completed redds by another female chinook. A fourth redd was constructed even later to the side of redd number two, which resulted in a multiple redd, forming a dune approximately 9 meters in length perpendicular to the flow, (Figure 6) by a total of 4 female chinook.

This singular observation occurred with the largest escapement in 22 years during the lowest spawning flows in an area of restricted suitability. Chinook were compelled to spawn in the limited and hitherto unspawned areas since the majority of dunes were partially or completely exposed and unsuitable for spawning.

Figure 4




FLOW
REDD KEY

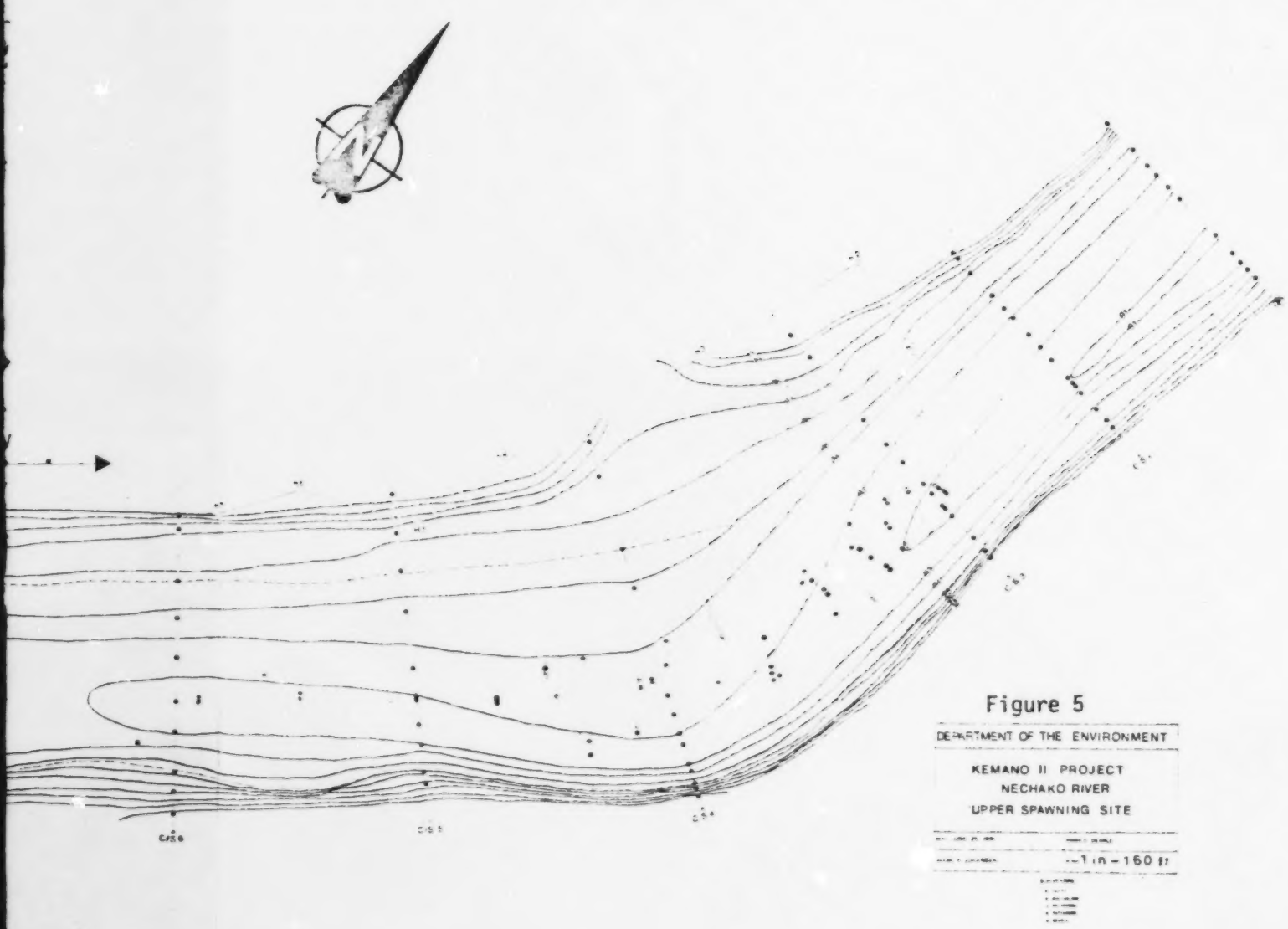


Figure 5

DEPARTMENT OF THE ENVIRONMENT

KEMANO II PROJECT
NECHAKO RIVER
UPPER SPAWNING SITE

1 in = 160 ft

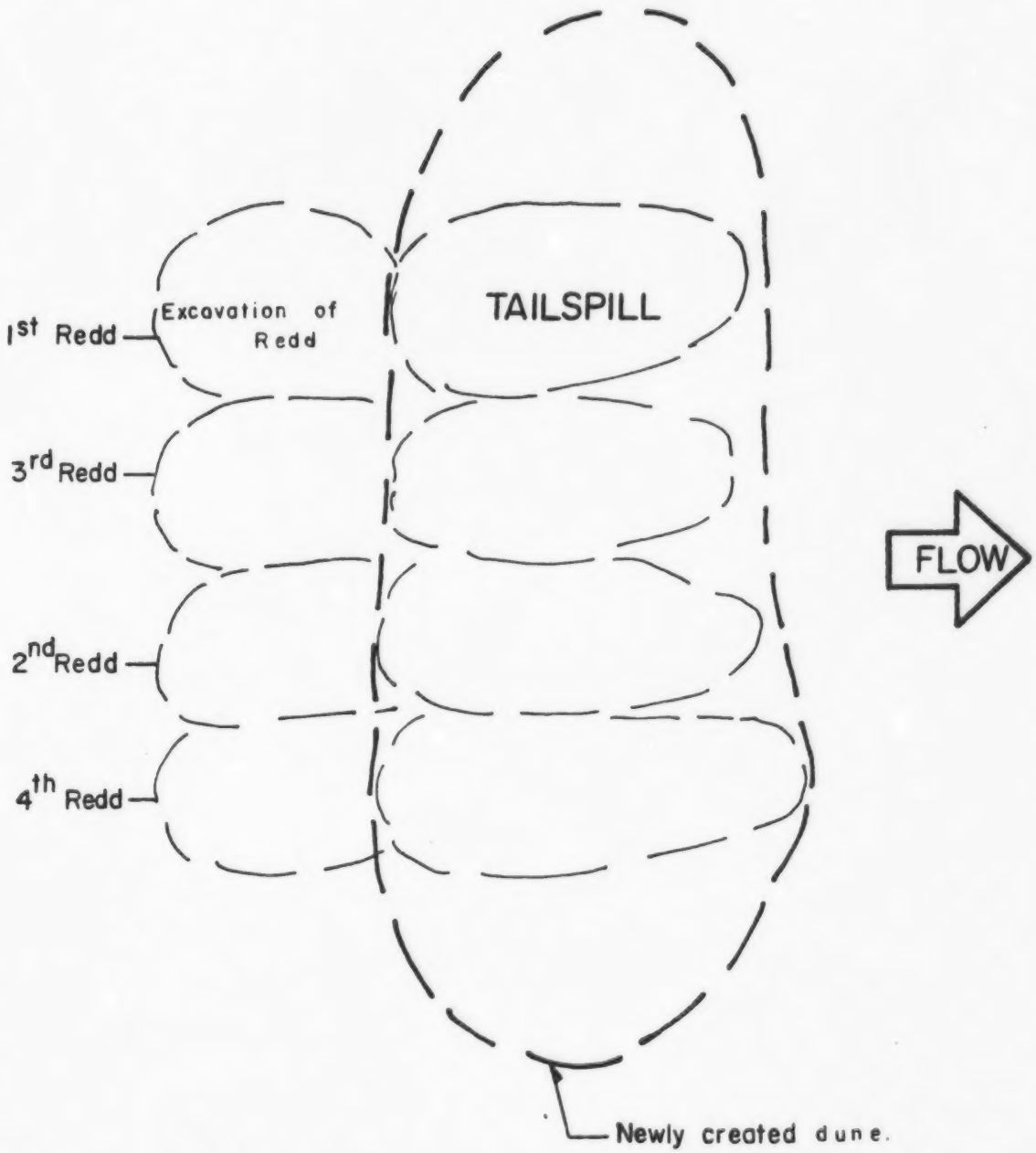


Figure 6. A new dune formation - multiple redd.

3.2.2 Enlargement of an Existing Dune

Two female chinook salmon positioned their redd excavation at either end of an existing dune during the period of September 5 to September 12, 1974, (Figure 7). This new redd construction extended the length of the already existing dune perpendicular to the streamflow by a further 6 meters.

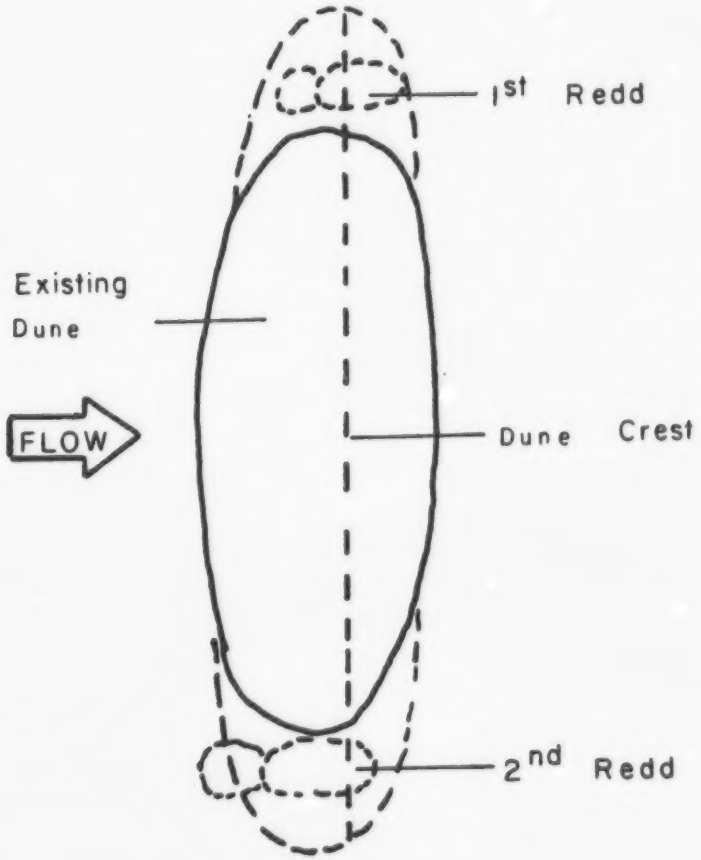


Figure 7. Enlargement of an Existing Dune.

3.2.3 Branching of an Existing Mound

A dune may become branched when local obstructions (rocks) prevent lateral extension. Two female chinook salmon completed redds slightly upstream of a boulder extending an unbranched dune during the week of September 5 to 12, 1974. The following week, a third and then a fourth female constructed redds downstream of the boulder bending the dune formation around the boulder. Thereafter, during the period of September 12 to 26, 1974, a fifth female salmon positioned her redd upstream of the boulder adjacent to the bend. The resultant multiple redd or dune was branched with two newly formed lobes similar to that shown in Figure 8.

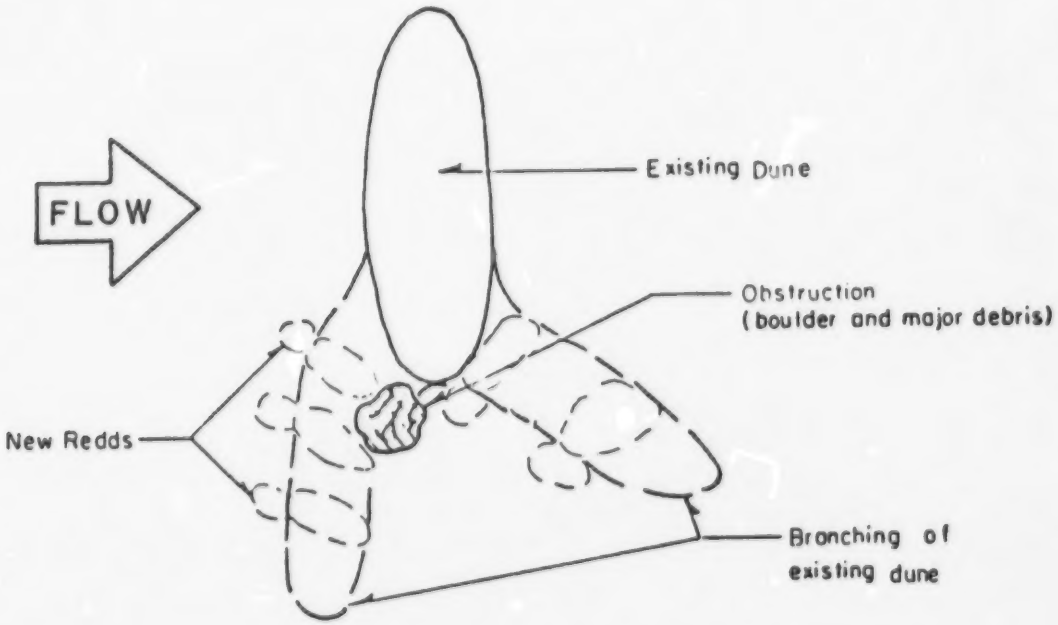


Figure 8. Branching of an existing dune.

3.2.4 Conservation and Extention of Existing Dunes

Five pairs of chinook salmon constructed redds along the length of an already existing dune during the spawning period. The first redd was excavated on the upstream slope at one end of the dune and a second redd was created at the opposite end during the same week, (September 5 to 12, 1974). Third and fourth redds were excavated on the upstream face of the existing dune approximately 7 meters from the first redd, during the following week. Finally, a fifth redd was excavated at the end of the dune in the third week.

This multiple redd had the effect of increasing the length, as well as re-establishing the dune formation, (Figure 9).

4.0 CONCLUSIONS

Discharge was maintained between 25.5 to 28.3 cu.m./sec. (900-1,000 cfs) by regulating the discharge in the Upper Nechako River during the chinook salmon spawning period during 1974. The chinook salmon spawned in those historic spawning areas that contained large dunes that were submerged. Observations of spawning chinook salmon during this period revealed that dune formation is associated with the activities of spawning chinook salmon. The formation of multiple redds created new dunes,

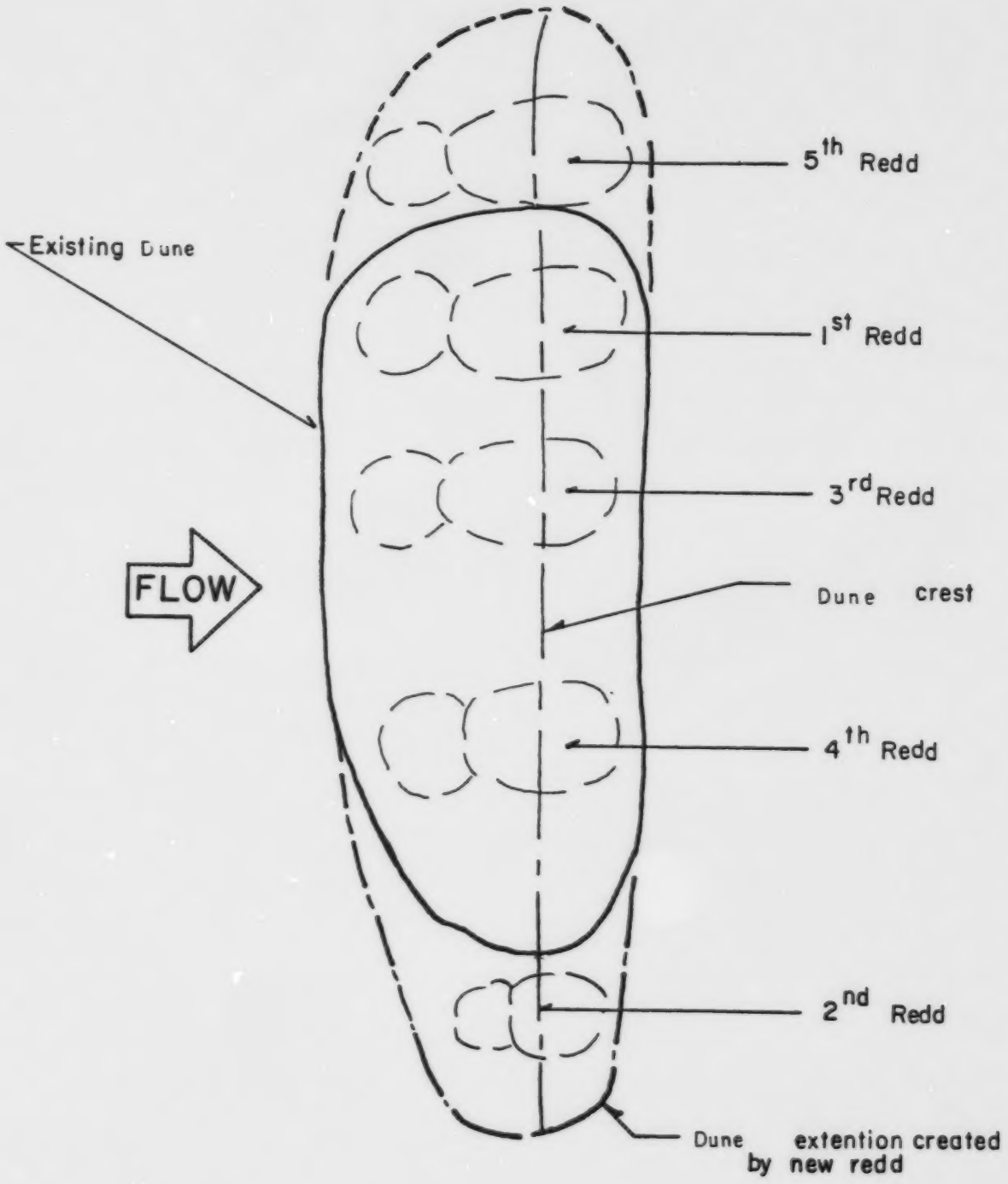


Figure 9. Conservation and Extension of an Existing Dune.

caused the branching and extension of existing dunes, and conserved existing dunes that would otherwise probably become eroded back to a plane surface after several years. No redds were observed to have been superimposed by a spawning female on a redd previously constructed that year.

During redd construction, chinook salmon held position in the low velocity zone located on the immediate downstream margin of the dune, which may provide the salmon with a means of conserving energy. Cooper (1965) found that enhanced water circulation through gravel occurs as a direct result of the hydraulic dimensions of spawning redds. Multiple redds that form these dunes must improve the intergravel incubating conditions and therefore contribute to survival and subsequent maintenance of the Upper Nechako chinook salmon population.

Another known area with similar dune formations associated with chinook salmon spawning is found in a section of the Morice River, 0.8 km. downstream from the Morice Lake outlet, Appendix I, Plate 8. Mr. T. Gjernes of the Pacific Biological Station has also observed similar dune formations at Canoe Crossing, 5 km. downstream from Chilko Lake on Chilko River. It is noteworthy that these three river systems (Nechako, Morice, and Chilko) are all buffered by headwater lakes that provide relatively stable fall chinook spawning flows.

The most recent reference to chinook spawning dunes is contained in a Report by Huntington (1985). Highlites from this report describing spawning dunes follow:

"Spawning Dunes

Early in this study it was noted that portions of the riverbed in many major fall chinook spawning areas in the Deschutes River are characterized by parallel bands of elevated gravel oriented approximately perpendicular to streamflow. These bands of "dunes" of spawning gravel were usually found in spawning areas which would have had fairly uniform hydraulic conditions without their persence. Dunes were generally found near the river margin or in association with islands, but were also present on some mid-channel gravel bars which were well used by spawning fall chinook.

The wave form of spawning dunes in the Deschutes River ranges from two to eight feet in amplitude and 20 to 60 feet in periodicity. Two to five dunes typically occur in series within a particular spawning area, although a few series containing more parallel bands of spawning gravel than this were found in the river. Because these spawning dunes are an important feature of many prime spawning areas for fall chinook in the Deschutes, the value or implications of their presence in these areas was investigated. The results of this investigation indicate that these structures are usually a desirable component of prime spawning areas for salmonids.

Dunes are constructed by salmonids, typically fall chinook salmon, spawning in close proximity to one another year after year. This phenomenon, although not widely reported, has been observed in many rivers in the Pacific Northwest, northern California, British Columbia and Alaska. Chinook salmon construct and maintain persistent dunes in the Sacramento River near Redding, California (K. Buer, California Dept. Water Resources, Red Bluff, CA., pers. comm.), and at Aleck Riffle on the Feather River, California (K. Buer, pers. comm.; D. Painter, Cal. Dept. Fish and Game, Oroville, CA. pers. comm.). Dunes in these systems have amplitudes of 2-5 ft. and a periodicity of 20-50 ft."

"Spawning dunes are found most commonly in regulated rivers or in rivers downstream of large lakes. There are two apparent reason for this. First, the hydrology of most regulated rivers and those below large natural lakes

typically lacks pronounced peak flows which would tend to remove dune creasts and fill-in troughs each year. Second, regulated rivers and those immediately below large lakes typically have limited bedload recruitment of gravels which would tend to physically prevent the progressive build-up of spawning dunes.

The physical characteristics of most spawning dunes make them desirable features of salmonid spawning areas. Unless they become to pronounced or too coarse, these structures can afford fish excellent conditions for redd digging and egg survival. The head differential from crest to crest may increase downwelling of water through the gravel to a greater degree than a single redd would. Hydraulics for redd digging and egg deposition are improved adjacent to an existing redd or at the end of a spawning dune, causing initial dune formation and the lengthening of these structures over time.

Fish use the leading (upstream) edges of the dune crests for spawning, finding resting or holding conditions favorable in the troughs. This causes individual dunes to "migrate" downstream in a particular area over time. Older dune series can develop undersirable contours and be abandoned by spawners if fresh bedload is not delivered to the series periodically. Spawning materials can eventually become too coarse and the dunes too pronounced for the fish to use them. A similar phenomenon has been observed in the Feather River, California, where the development of undesirable dune contours led to the abandonment of a particularly large spawning dune below Oroville Dam (D. Painter, pers. comm.)".

"Spawning dunes are generally associated with areas heavily used or once heavily used by spawners. However, they do not necessarily indicate that redd superimposition is occuring. On the contrary, they in some cases may indicate optimum utilization of available spawning habitat. For example, dune structures in the Feather River, California below Oroville Dam lose their characteristic appearance when spawner densities exceed the capacity of spawning areas there (D. Painter, pers. comm.)".

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These observations were a result of studies undertaken by the Fisheries and Marine Service in 1974 to assess the effects of the Kemano II hydroelectric proposal on the Nechako River and its salmon stocks. Special thanks for their field assistance is expressed to Messer's. S. MacFarlane, J. Patterson, R. Patterson and D. Dearle. The manuscript was reviewed at various times by Messers. Wm. Schouwenburg, D. Barrett, R. Bams, R. Hamilton and Dr. I. Birtwell.

APPENDIX

Plate 1 Lateral view of area described in Figure 1. Note the gravel size in foreground which is homogeneous for entire spawning area. Discharge (3540-450 cfs June, 1974).

Plate 2 Downstream view of the Upper Study site in the Nechako River illustrating the crests of the dunes (surface riffle bars) during extreme low flow discharge (350 -450 cfs) June, 1974.

Plate 3 Technicians located at a cross-section line responsible for lateral movement of mobile surveyor using secondary rope attachment.

Plate 4 Mobile surveyor in boat holding survey rod with fluorescent flagging above the site of redd excavation. Note the rope attached to boat which is controlled by technicians located at cross-section line.

Plate 5 Surveyor with transit, and permanent survey station (stake) driven into river bed.

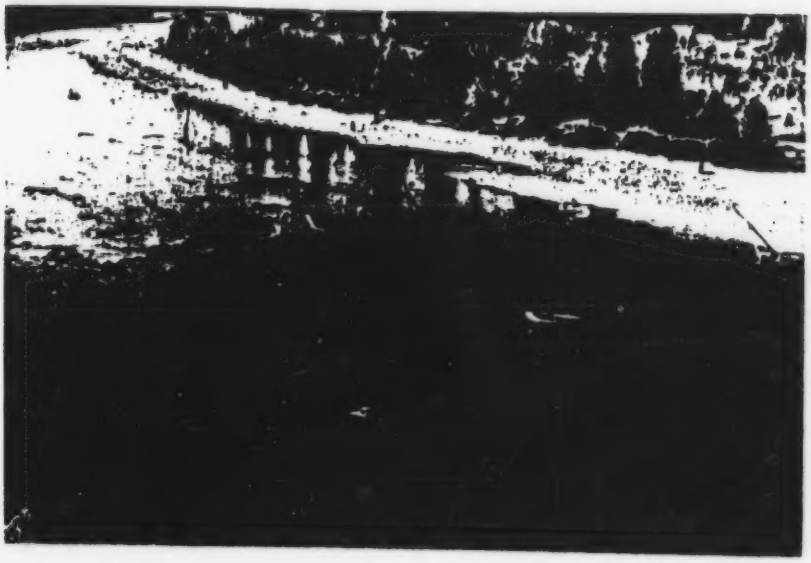

Plate 6 Upstream view of the upper study area. Observe the boat and mobile surveyor and one technician. Note the large dune to the left of the boat (riffled area).

Plate 7 Downstream aerial view (125 meters above river) of Upper Study site indicating cross-section #12 (bottom of picture) and cross-section #11. Discharge (900-1,000 cfs), September, 1974.

Plate 8 The riverbed configuration indicated in this photograph is the result of dunes created by an escapement of 2,000 - 4,000 chinook salmon spawning in this section of the Morice River, .8 km. downstream of the outlet of Morice Lake, B. C.